

ENAMELS

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ADDITIVE METHODS FOR CALCULATING THE PROPERTIES OF ENAMELS

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The possibility of calculating the CLTE, viscosity, and surface tension of frit melt for undercoat enamel using different methods with variation of the Fe_2O_3 content and taking into consideration the experimental data is examined. Knowing the percentage ratio of three initial frits in the undercoat enamel and their experimentally determined properties, additive methods are used to determine the properties of the undercoat enamel.

Many computational methods for determining the properties of glasses and enamels are known. In using these methods, their specific features are taken into account: lower accuracy as compared with the experimental data and application limited to certain definite composition ranges. Nonetheless, only the combined application of the computational and experimental methods permits arriving at the correct results.

In the present work, together with experimental determination, the possibility of calculating the CLTE, viscosity, and surface tension of the frit melt for the undercoat enamel by different methods with variation of the Fe_2O_3 content is examined. Knowing the percentage ratio of three initial frits in the undercoat enamel and their experimentally determined properties, additive methods have been used to determine the properties of the undercoat enamel. Appen's method was used to calculate the CLTE for frits theoretically. A characteristic feature of this method is that instead of mass units, characterizing the oxide content in the enamel, it employs molar units — fractions or percentages. The presence in the enamel of components with variable partial properties not only complicates the calculations but it also decreases the accuracy of the results. The average CLTE can be calculated by Appen's method to within $\pm 2.2 \times 10^{-7} \text{ K}^{-1}$ [1].

Figure 1 compares the experimentally determined CLTE data and the computed values obtained by Appen's method [1].

The values of the CLTE of samples of the initial frits GK-321, GK-326, and GK-331 depend directly on the

amount of alkali oxides in the melt (it decreases negligibly). The CLTE of these samples lies in the range $(90 - 129) \times 10^{-7} \text{ K}^{-1}$, which is explained by the closeness of their compositions.

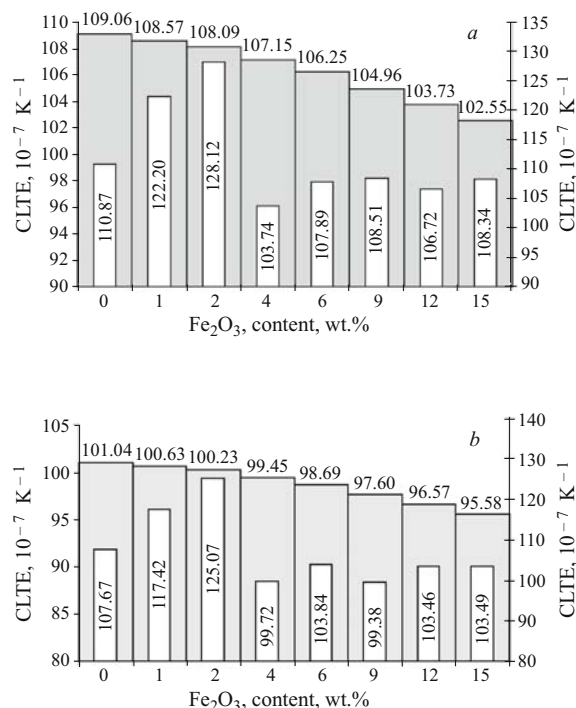


Fig. 1. CLTE of GK-321 frit (a) and undercoat frit (b) versus the iron oxide content. The computed values of the CLTE, obtained by Appen's method, are shown in italics.

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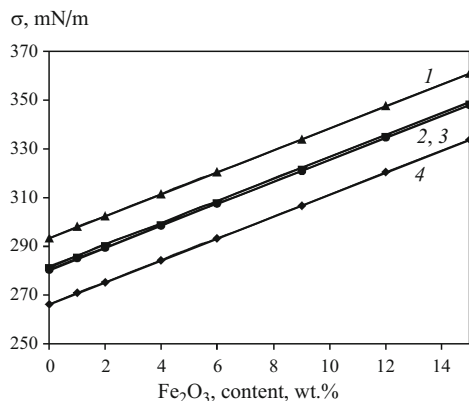


Fig. 2. Surface tension of different enamel compositions versus Fe_2O_3 content (according to Dittsel'): 1) GK-331 frit; 2 and 3) GK-326 frit and undercoat enamel; 4) GK-321 frit.

The discrepancy in the additive calculation of the CLTE of the undercoat enamel from the experimental properties of the three frits is no more than 10% (Table 1).

Using the additive formula, we computed the logarithm of the viscosity at 580°C. The computational error likewise does not exceed 10% (Table 2).

The surface tension σ for the known compositions was calculated by Dittsel's method [1]. Dittsel' proposed using the additive coefficients to calculate the surface tension. These coefficients are valid for temperature 900°C and comparatively acidic compositions containing less than 25 wt.% Na_2O . The values of the surface tension for more basic melts are substantially lower than the experimentally measured values. The presence in the enamel of surface-active (or intermediate) oxides, such as P_2O_5 , As_2O_5 , Bi_2O_5 , Sb_2O_5 , K_2O , Rb_2O , Ti_2O , and PbO , presents serious difficulties in the calculation of the surface tension. In the absence of these oxides the average accuracy of the σ measurements is $\pm 1.5\%$. The results obtained with Dittsel's method [1] are presented in Fig. 2.

The computed dependences of the surface tension on the Fe_2O_3 content are linear for all enamels studied. The surface tension increases with the iron oxide content (see Fig. 2). Experimental measurements of the surface tension by the "stationary" drop method made it possible to obtain the extremal dependence $\sigma = \sigma(\text{Fe}_2\text{O}_3)$ [2]. In all cases a minimum was observed for iron oxide content 8–10%.

An additive calculation of the surface tension of the undercoat enamel is presented in Table 3. In the present case, apparently, the additive computational formulas are completely unsuitable. In contrast to the CLTE and the viscosity, which are bulk properties of the enamel, the surface tension is regulated by the composition of the surface film. The composition of the gas phase and the presence of surfactants lead to large discrepancies between the computational and experimental values.

In summary, knowing the CLTE and the viscosity of the initial frits it is possible to find a composition for undercoat

TABLE 1.

F_2O_3 content, wt. %	CLTE, 10^{-7} K^{-1}	
	experimental values	data of the additive calculation
0	107.670	107.053
1	117.420	117.019
2	125.070	119.467
4	99.720	100.773
6	103.840	100.849
9	99.380	102.945
12	103.460	99.373
15	103.490	97.288

TABLE 2.

F_2O_3 content, wt. %	$\log \eta$	
	experimental values	data from additive calculation
0	10.440	10.374
2	10.540	10.606
4	10.580	10.528
6	10.700	9.885
9	10.400	10.110
15	10.500	10.447

TABLE 3.

Fe_2O_3 content, wt. %	Surface tension, mN/m	
	experimental values	data from additive calculation
0	72	168.9
1	211	203.0
2	229	142.1
4	91	269.9
6	210	200.7
9	167	141.9
12	200	161.7
15	247	219.4

enamels which possess the required properties. However, it is much more accurate to determine the properties of the enamels with complex composition experimentally.

REFERENCES

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